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Van Fraassen on Empirical Equivalence Argument and Interpretations of Space-time*

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【Abstract】This essay criticizes Van Fraassen's argument for empirical equivalence among competing theories, which is based on his interpretation of Newtonian space-time. I argue that his misleading interpretation of the ontology of absolute space-time results in his ineffective attacks against a residual structure of space-time, absolute velocity. Van Fraassen's argument basically misleads us into empirical equivalence in that his literal reading of Newtonian space-time disregards a variety of aspects of its model.

【Key Words】Scientific Realism, Empirical Equivalence Argument, Interpretations of Space-time, The Ontology of Space-Time, Models and Theories

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1. Introduction

In order to explain the success of science, realists claim that theoretical terms in scientific theories are referring expressions. By means of an underdetermination thesis, Van Fraassen in the *Scientific Image* denies that theoretical terms precisely correspond to the world, claiming that empirical adequacy is a preferred standard for the acceptance of a scientific theory.[1] Underdetermination of theory results in indeterminacy of the winner among rival theories. The most crucial evidence for this thesis is the existence of empirically equivalent but logically incompatible theories. Even in the extension of theory, the victor among empirically equivalent rivals is claimed to remain undetermined. As a constructive empiricist, he considers relations between scientific theories and the world to be weaker than realists think.

This essay examines Van Fraassen's argument for empirical equivalence among competing theories. His line of reasoning is based on his interpretation of Newtonian space-time. I think that his literal reading of ontology of absolute space-time results in his ineffective attacks against a residual structure of space-time, i.e., absolute velocity. Also, he applies his argument to the cases without considering not only various roles of elements of the model, but also diverse purposes of explanations of physical theories. Through investigations of detailed roles and interpretations of space-time models, I shall attempt to undermine

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[1] Van Fraassen, B. C. (1980), *Scientific Image,* Oxford University Press.

his contention.[2)] A model of space-time is analogous to a toy vehicle that is composed of separate pieces with different roles. Certain parts such as motors, frames, and shafts are essential to enable vehicles to move. On the other hand, there are also residual parts such as flags, decoration, and dummy drivers. Absolute velocity in the space-time model can be compared to flags, or maybe dummies in a toy vehicle. We need to distinguish between the parts of a theory that do real work and the parts that are idle. At the end of this paper, I shall present a promising direction for distinction between them. And according to the different functions of the parts of a model in the theory, the meanings of reality should be considered separately.

2. Van Fraassen's Empirical Equivalence Argument

In the history of philosophy, there have been many skeptics who have questioned the thesis that a theory is fully determined by induction from empirical evidence. Descartes doubted the foundations of empirical knowledge due to the possibility of reconstructing our perceptual experiences in completely different ways that the devil might deploy them. Hume, the champion of skeptics against causal knowledge, deconstructed causal judgments into psychological projections that are empirically equivalent but logically incompatible. The history of contemporary philosophy

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2) Surely, I cannot dismiss Van Frasssen's general argument just because his specific example is dubious. This paper targets only Van Fraassen's argument that is based on the interpretation of space-time.

has had a variety of their successors who are highly sophisticated in their technical details: Quine's inscrutability, Reichenbach's conventionality in geometry, and many others.

In spite of the endless skeptical attitudes to the rationality of inductive knowledge, the 20th century has experienced remarkable achievements in the empirical sciences. If the ultimate goal of their progenitors of philosophy is achieved in the scientific traditions, the position of skeptics will be degraded to mere cynics. Scientific realists claim that theoretical terms in scientific theories must be understood as referring expressions so that the success of science should not be a miracle. Van Fraassen, however, has argued against a realist's interpretation of theoretical terms by means of empirical equivalence of rival theories, which results in underdetermination in theories.[3] He is also different from the preceding skeptics in that he does not disbelieve in the foundations of empirical sciences but sets a pragmatic criterion for the acceptance of a theory. In the situation of empirical equivalence of competing theories, we cannot decide the winner by the standard of truth even in the extension of the theories. Therefore, he claims that truth as correspondence is an inadequate epistemological standard and empirical adequacy should be admitted as a criterion for the acceptance of a scientific theory.

Van Fraassen's argument that leads us to empirical equivalence is closely related with his understanding of the philosophy of space-time. His position on the debates between the Newtonians and Leibniz on the ontology of space is that the relationism of

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[3] Van Fraassen (1980), section 3 'To Save The Phenomena'.

Leibniz, who stands for constructive empiricism, can be also admitted as an empirically adequate interpretation of space.[4] In realists' interpretations of Newtonian mechanics, Van Fraassen has claimed, we can construct an infinite number of empirically indistinguishable but logically incompatible theories, resulting in an epistemological impasse. The scholium of Newton's Principia begins with distinctions of 'saved phenomena' from 'postulated reality' and 'apparent motions' from 'true motions' of a particular body.[5] Apparent motions of a planet are relative motions that look different according to the position of an observer. On the other hand, true motions are those that can be uniquely defined in Absolute Space that is a mathematical model of Newtonian mechanics. Van Fraassen claims that Newton thought Absolute Space exists, and proceeds his argument under this assumption.[6] TN is defined as Newtonian mechanics, and *TN*(x) as a theory with the additional axiom that the center of mass of a solar system moves at constant velocity x with regard to Absolute Space. Then, Newtonian dynamics asserts that *TN*(0) is an empirically adequate theory. If *TN*(0) is empirically adequate, we can construct an infinite number of *TN*(v)s that are also

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4) Van Fraassen (1970), section Ⅳ.

5) See Newton (1729) or Van Fraassen (1980) pp. 44-46.

6) In Van Fraassen (1980, p45, my italics), he says that "When Newton claims empirical adequacy for his theory, he is claiming that his theory has some model such that all actual appearances are identifiable with motions in that model. … *Newton's theory does a great deal more than this. It is part of his theory that there is such a thing as Absolute Space*…" However, whether Newton thought space has existence like an ordinary matter is still controversial between philosophers of science.

empirically equivalent but logically incompatible with *TN*(0). This case results in underdetermination of theory, in which there is no way of selecting the winner that represents the real world.

Van Fraassen's line of reasoning can be traced as follows. Absolute Space, if realistically interpreted, can be understood as an existing entity. Since Absolute Space is an essential part for obtaining observable results of apparent motions of a body, its absolute position is also a physically significant theoretical term. *Though absolute velocity, which is the ratio of change of absolute position, cannot be measured, it is also a well-defined term in the kinematics of Newtonian space-time*. Consequently, *TN*(0) and *TN*(v) represent different pictures of the world. The main line of reasoning in Van Fraassen's argument is that empirically equivalent but logically incompatible theories result from the realist's interpretation of space. Consequently, realists about space-time, he has claimed, confront an epistemologically undesirable situation. On the other hand, constructive empiricists have a pragmatically desirable condition for the purpose of scientific practices since they have no burden of selecting the theory that correctly depicts the real world.

3. A Criticism of the Empirical Equivalence Argument with Regard to Modeling

Van Fraassen's argument has the same thread as the debate between substantivalists and relationists on the ontology of spac e.[7] The object of Van Fraassen's attack can be called a substantivalist who interprets Absolute Space as an existing entity like ordinary matter. However, even if unobservable entities play an essential role in deriving observable results, scientific realists need not interpret those theoretical entities as substance. Before we mate proper correspondence between a scientific theory and the real world, we should initially comprehend the structures of the theory. In the context of Newtonian mechanics, the structure of space-time provides *a sufficient superstructure* to explain absolute motions, i.e. absolute acceleration. *Absolute position and velocity are remnant structures that can be deleted in Newtonian mechanics*. Ontologically economical neo-Newtonian space-time can be constructed without these two residual concepts.[8] Then, let's define *TN** as a theory *devoid of* absolute position and velocity. *TN*(0), *TN*(v), and *TN** are all empirically equivalent

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7) The ontology of space (or space-time) has been debated under the name of Substantivalism-Relationism controversy. The debate between two parties are concerned with the nature of existence of space. Substantivalism claims that the parts of space have existence akin to matters in it. That roughly means that space and time exist even when all matters extinguish from the world, and spatio-temporal structure is invariant without regard to the positions of an observer in it. On the other hand, relationists argue that space is a possible relation of matters or events, denying that space has independent existence. These metaphysical disputes play important roles in the development of physical theories.

8) See, for example, Sklar (1974). The structure of neo-Newtonian space-time has absolute simultaneity, i.e. we can define whether or not two points or events are on the same timeslice. Hence, we can uniquely define temporal separation between every point in space. But the identity of points through time is not admitted in this space-time. And absolute acceleration is measured by means of the deviations of a particle's worldline from geodesics of free-falling particles.

since observational results cannot be distinguishable. Therefore absolute velocity does not contribute to providing identical observational consequence of those three *TN*s. Consequently, we can conclude that absolute position and velocity play no significant role in providing the result of empirical equivalence of *TN* group, since *TN** can be defined without them.[9] By means of attaching an original theory with structures that make no physical contribution, we can easily construct an infinite number of empirically equivalent theories via those additional structures. If structure *A* is logically independent of *TN*, the conjunction of *TN* and *A* does not make a counter-effect on the empirical equivalence of *TN* since it is logically weaker than *TN*. In our case, absolute velocity is an insignificant theoretical structure *A*, which misleads us into empirical equivalence thesis.

In the model of absolute space-time without absolute velocity, the empirical equivalence argument does not work. Since absolute velocity is not a physically significant concept with observational consequences, it is not the variable that discriminates models of Newtonian space-time. Thus, *TN*(0) and *TN*(v) are not different models. Then, what misguides us into empirical equivalence? In the following text, two interrelated aspects of the interpretations of space-time models shall be presented. First, we have a variety

[9] Cho (1994) presents a similar argument with *TN** as a theory without absolute space. Relational theory of Barbour and Bertotti will be a possible candidate for Cho's *TN**. But their theory is not empirically equivalent with Newtonian mechanics, since it can measure the divergences of Newtonian mechanics that is based on the approximations of matter homogeneity. Hence, his example does not provide empirical equivalence to three theories.

of options of interpretations of space-time in which realists can escape empirical equivalence. (This shall be discussed at later section) Second, concerning residual parts of the model, Van Fraassen puts too much burden on the realists about space-time. To guarantee the safety of his antirealistic position, he made a realists' position as weak as possible and then attacked it. Considering practices of science, this weakened realist's standing is aberrant from essential intuitions of realists. For the latter one, I shall look into Van Fraassen's understanding of scientific theory, the semantic view.

Van Fraassen stands for the semantic view of a scientific theory. In this view, a scientific theory is understood not as the set of axioms or uninterpreted equations but as a family of models that depict the relations between abstract equations and the world.[10] The models of a physical system can be constructed in various ways. However, this multitude of possible models is *not necessarily* an evidence only for anti-realists of scientific theories. According to the degrees of relevance between the components of a model and the world, each model can be a sign for either realists or antirealists. Then, how much relevance is necessary in scientific realists' models?

Van Fraassen calls a model's parts that represent observational phenomena 'empirical substructures'. A model of theory, constructive empiricists claim, is said to be empirically adequate if its empirical substructures are isomorphic to observable data called 'appearances of the world'.[11] On the other hand, every

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[10] Van Fraassen (1980), pp. 64-67.

detail of the realists' model is required to represent the world as it is.[12] In the model of theory, however, there are not only structures that represent the world, but also theoretical postulations that are necessary for deriving observable results. The theoretical postulation that molecules of ideal gas, for example, are inelastic particles does not precisely describe the world, but plays an essential role to construct the physical model of ideal gas. Then, it is too much burden for scientific realists if even theoretical postulates are required to represent the world precisely. Even if a theoretical postulate that does not depict the world as it is has the same causal influence with one of the real world, it can be interpreted realistically.[13] Thus, the reality of each component with different roles should be judged on different standards.

It is the same for models of space-time theory. Not all the aspects of a model of space-time are connected with the real world with the same weight. Some parts of a model are logical structures, others represent the world, and others are remnant structures that are only for mathematical convenience. Even

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11) Van Fraassen (1980), p. 64.

12) Van Fraassen (1980, p. 47, my italics) says, "to believe a theory is to believe that one of its models *correctly* represents the world. You can think of the models as representing the possible worlds allowed by the theory: one of these possible worlds is mean to be the real one."

13) Hardin and Rosenberg (1982) present flexible interpretations of the reference of theoretical terms by means of their causal role. Even if objects that theoretical terms make reference to do not exist literally, their causal roles that continue to operate in the theoretical changes, they claimed, are admitted as referring expressions. Although their claim was concerned with theoretical entities, we can apply this idea to theoretical postulations that conserve causal roles in the abstraction of physical pictures.

hard-core realists will not claim for the reality of remnant structures. In particular, space-time models, though they are for the derivation of trajectories of particular bodies that can be observed, have more unobservable theoretical elements than empirical substructures. *Various theoretical elements have different tasks in the theory*. Then, it is too much burden for realists if the same standards for realism should be set regardless of their various characters of components of a model. Since absolute velocity is a residual structure of space-time, realists about space-time are not vulnerable from an anti-realist's attack on the multiple ontology of reference frame that has a different absolute velocity. We can confirm this with the existence of neo-Newtonian space-time in which absolute acceleration can be defined without absolute velocity and position. *The component without which alternative models can be constructed should not be regarded as an essential part of the theory*. Also, within the theory of relativity that is the extension of Newtonian mechanics, inertial structure is a still fundamental one without absolute velocity. Hence, absolute velocity in Newton mechanics does not have any connection with the real world. Van Fraassen, applying his argument to a remnant structure of space-time, leads us to empirical equivalence.

4. A Criticism Regarding Interpretations of Space-time

Van Fraassen states in his *Scientific Image* that we have two ways to get the picture of a physical theory; the first is to understand the structures of a theory and the second is to figure out the relation of the theory to the world and to the theory-user. He also says that he has dealt mainly with the latter without considering the former.[14] However, the lesson of the foregoing section is that *we need initially consider the structures of a physical theory for the purpose of proper correspondence of the theory with the world*. Before understanding the appropriate relation between the theory and the world, we need to decide the structures themselves by answering such questions as; which parts are essential for driving observable substructures, and how each of the core elements are organized into the whole. These activities can be called the 'interpretation' of a theory. Interpretation is concerned with *the way* that the models' components, which lie behind observable ones, can be organized while interpreters conserve the empirical contents of a theory.[15]

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14) Van Fraassen (1980) says "Studies in philosophy of science divide roughly into two sorts. The First, which may be called foundational, concerns the content and structure of theories. The other sort of study deals with the relations of a theory on the one hand, to the world and to the theory-user on the other hand." (p. 2) And that "I am concerned with the relation between physical theories and the world rather than with that other topic, the structure of physical theory." (p. 67)

15) "Here we must distinguish attempted completion by means of extensions with new empirical content, and by interpretations, which render a fuller account, and *by interpretations, which render fuller account but with no added empirical content.* The working scientist is mainly intent on the former, and may be dismissive of the empirically superfluous"factors in the latter. But the interpretational demands of What is really going on (according to this theory)? or even the more modest How could the world possibly be how this theory says it is?……" (Van Fraassen 1991 p. 9, my italics)

Hence, even after postulated entities is chosen as a result of the interpretation, one who does not have additional empirical evidence can be either a realist or an anti-realist about those entities.

Van Fraassen's interpretation on space-time theory does more than this. He insists that Newton thought space exists. (See note 5) Hence, his criticism through the structures of Newtonian space can be an attack against realists. In this context, however, it seems that he associates two separate aspects in a physical theory, that is, the interpretations of a theory and the existence of theoretical entities. It shall be shown in this section that this underlies his argument and also weakens his line of reasoning. Van Fraassen has considered the problem of interpretation as the reality of theoretical entities in our case.

Substantivalism is considered to be a received view of the interpretation of Newtonian space-time. According to this view, spatio-temporal structure is invariant regardless of the positions of an observer and space-time exists even without matters or events in it. Van Fraassen asserts that Newton thought there is such a thing as Absolute Space. Therefore, an empirical equivalence argument can be paraphrased as follows, '*since substantivalism that leads us into empirical equivalence of space-time theories is realism about an entity called space-time, the realism about theoretical entities is an epistemologically unwarranted attitude toward scientific theories*' [SR]. However, the relation between substantivalism and realism is not so straightforward as many philosophers of space-time have stated.[16] The most decisive argument for the reality of absolute space-time is Newton's thought experiment called 'Newton's bucket'. But Stein has argued that this argument was conducted not to prove that absolute space exists but to show that absolute motions can be defined in Newton's mechanics.[17] Since what is important in Newton's mechanics is the distinction between inertial frames and non-inertial, they questioned 'whether the objective existence of Absolute Space need have been the central issue for Newton' (Toulmin quoted in Stein, 1967). Toulmin's and Stein's moral is that *we need to distinguish between the structures of a theory and theory-users' attitudes toward theoretical entities* within the context of Newton's mechanics.

Theory-users' ontological attitudes toward theoretical entities depend on the context of an individual theory.[18] For example, the reality of a corpuscular particle that has both definite position and velocity is admitted in the frameworks of classical mechanics. But highly precise locality and even objective reality of matter is threatened in quantum mechanics.[19] The vector potential is utilized just for mathematical convenience in classical electromagnetism. However, the quantum effect measured by Aharonov and Bohm provides more ontological significance for the vector potential than classical phenomena have done.[20] Hence,

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16) Earman and Friedman (1973) consider substantivalism as a realistic interpretation of space-time. But Belot (1996), Butterfield and Isham (1999) deny that conventional arguments are the debate between realism and antirealism about space-time.

17) Stein (1967) pp. 275-277.

18) For more detailed discussions, see Cartwright (1983).

19) For detailed discussions in philosophical view point, see Chang (1995).

ontological belief in theoretical entities is bounded in the individual model. Thus, ahead of considering the physical reality of theoretical entities, we need to fix the context of the theory in which those entities operate. On the other hand, scientific realists expect a stronger sense of reality: belief regardless of a specific model. Then, even after theory-users make decisions about which entities need to be postulated, they can be either realist or anti-realist (in the stronger sense) about these entities. Hence, there are noticeable gaps between understanding the structures of a theory and ontological attitudes.

The interpretations of space-time, substance or relation, are concerned with the structures of models of space-time *behind* empirical substructures, not with the correspondence between the theory and the world. In the context of a highly theoretical explanation in which direct methods for confirmation of the reality of entities are not easily available, theory-users' ontological attitude is not determined even after their interpretation is established. Consequently, Van Fraassen's argument that *relates substantivalism with realism about theoretical entity* [SR] is implausible in that it makes a connection between different aspects of the physical theory.

5. Possible Realists' Positions that are Safe from Van Fraassen's Argument

My viewpoint on the interpretation of space-time might be

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[20] For detailed discussions in philosophical view point, see Belot (1998).

confronted by a counter argument that my accusation is off the point of Van Fraassen's argument against scientific realism. If he, my opponents might say, were to bear *realists among substantivalists* in mind, my criticism against him would be ineffectual. His argument, they might say, is that realists who think of space as substance are led to empirical equivalence of theories regardless of whether realism is an appropriate ontological attitude toward substantivalism. There are indeed substantivalists who think of themselves as realists about space-time.[21] Even in that case, Van Fraassen's argument, it seems to me, still has a limited effect against realists, since there are other options that save them from Van Fraassen's attacks.

Van Fraassen has aimed his argument at the realists who interpret space as substance. But as we have seen before, one who claims to be a substantivalist does not have to be a realist about space. Conversely, not all realists about space are substantivalists. Relationists who think of space as possible relations between bodies can believe that space exists.[22] Also, the realist about space does not necessarily argue for the existence of

21) Friedman and Earman (1973) are typical examples of them.

22) DiSalle (1994) reads Alexander (1956) and Earman (1989) as presenting Leibniz's relational theory as the evidence for physically objective reality of space-time. "His (Leibniz‟s) relational theory of motion therefore presupposes absolute simultaneity and Euclidean Geometry on space at each moment of time. …… The spacetime structure that Leibniz thus takes for granted is only that required by prerelativistic kinematics, without the affine structure required in order to speak of dynamical quantities like „absolute rotation‟and „dabsolute acceleration' …… *Leibniz, like Newton, attributes physically objective characteristics to space and time that do not depend on time*." (DiSalle, 1994, pp. 266-267, my italics).

space. Since space-time is the superstructure that makes the laws of motion work, realists about space need not admit the existence of an entity called space, but accept only *the reality of lawful connection* between space and absolute acceleration.[23] This kind of realist thinks that the laws of motion in Newtonian mechanics are the real aspect of our physical world. In this view, there is no lawful connection between absolute velocity and space. Since *TN*(0) and *TN*(v) are not defined with a variable that constitutes Newton's laws of motion, their differences are only conventional ones that do not have any physical significance. This fact is also manifest in Newton's equation. The physically significant quantity in Newton's equation is one that is invariant under coordinate changes. Since position and velocity are not invariant under the transformation of coordinates, they are not physically significant quantities in Newtonian mechanics. With this view of realism about space-time, realists can be safe from Van Fraassen's empirical equivalence argument.

In that case, do *the realists only for the laws* of space-time theory outperform *the realists about space-time entity*? If not, a way out that I have proposed will be inefficient. To carry out this discussion, I shall dissect explanations in physics again. Just as the parts of a model can be categorized according to their

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[23] DiSalle (1992) considers physical laws in Newtonian mechanics as essential parts of space-time theory. He argues that space-time structure does not explain the laws of motion: inertial effect. Instead, but the laws of motion define space-time structure in the context of Newtonian mechanics. Consequently, the reality of space-time theory should be understood as the existence of the laws of motion, not of the entity called space-time.

status in a theory, so can explanations in physics be. Cartwright (1983) has classified scientific explanations into two categories according to the type of law that constitutes the explanation; the one is a 'causal law' that clarifies causal processes of theoretical entities in specific phenomena, and the other is a 'fundamental law' that unifies various phenomena into coherent structures under higher-level explanations.[24) Only in the former, she has claimed that we can make unambiguous references to ontological commitment of theoretical entities. In the latter case, even if we can accept the effectiveness of explanations, truth as correspondence in a literal sense might not work out. Diverse illustrations that shed doubt on it can be offered in highly theoretical practices in mathematical physics such as anti-particle, quark, and string. Also, space-time theory can be considered as a typical example of them. Consequently, realists about highly theoretical explanations such as space-time theory should be more prudent about the meaning of reality in theoretical entities. Partial realism for lawful connections between theoretical entities can be a possible candidate for a safe position for scientific realists.

Van Fraassen presents the cases in Newtonian mechanics as a criticism against truth as correspondence in the acceptance of a theory. *But within the context of the theory of space-time, truth as correspondence might not be acknowledged*. Consequently, he selects an inappropriate example for the support of underdetermination

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24) Cartwright (1983) does not authorize the reality of fundamental laws itself, but moderate realists who reject the existence of theoretical entities in theoretical explanations may admit the reality of lawful connection between them.

thesis. The remainders that might bite the bullet are hard-core realists who admit ontological commitment of substantival space-time. However, in the interpretation of absolute acceleration that is defined as deviations of a particle's worldline from geodesics of free-falling particles, they can dispense with absolute velocity and be also safe from the criticism of Van Fraassen.

6. Conclusion

I have argued that Van Fraassen's argument misleads us into empirical equivalence since his literal reading of Newtonian space-time disregards a variety of aspects of a model. He neglects not only various roles of parts of the model, but also diverse purposes of explanations: for unification or for causal clarification. According to the different functions of parts of a model in the theory, the meanings of reality should be separately considered. Since we have not an ultimate theory but diverse approximate theories, the components of a theoretical model are not completely organized but still open to many possible interpretations. Hence, the definition of realism is also waiting for elucidation in keeping with the development of scientific practice. Through the extension of theory, blanks in interpretations will be filled in, which will reveal a clearer picture of our world. By means of extracting essential parts of the structures, the philosophers of science tend to simplify the structures of science. But in the simplified images of science, we might observe only illusions of science.

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반 프라쎈의 경험동등성 논변과 시공간에 대한 해석

양 경 은

본 논문은 반 프라쎈의 뉴턴 시공간에 대한 해석에 기초한 경험동등성 논변을 비판한다. 필자의 주장은 반 프라쎈이 시공간에 대한 오해에서 절대속도라는 뉴턴 시공간이 가지는 여분의 구조를 통해 부적절한 비판을 낳고 있다는 것이다. 반 프라쎈의 경험동등성 논변은 모형의 다양한 측면을 무시한 뉴턴 시공간에 대한 부주의한 해석에 근거한다.

주요어: 과학적 실재론, 경험동등성 논변, 시공간에 대한 해석, 시공간의 존재론, 모형과 이론